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DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE TEXAS

24 Feb 95

MEMORANDUM FOR 3 CES/CEVR
ATTN: Ms. Sharon Stone
22040 Maple Street
Elmendorf AFB AK 99506-3240

FROM: HQ AFCEE/ERT
8001 Arnold Drive
Brooks AFB TX 78235-5357

SUBJECT: Completion of One-Year Bioventing Test, Elmendorf AFB, ST 43/55 Valve Pit 3-4 Area, ST 43/55 Pumphouse III Area, Site ST 61, and Site ST 71

The Air Force Center for Environmental Excellence (AFCEE) one-year bioventing test and evaluation projects at Elmendorf AFB have been completed. Attached are site maps (Figure 1) and two tables (Table 1 and Table 2) for each of the four sites listed above. Figure 1 provides general site information and Table 1 provides a summary of initial, six-month and one-year fuel respiration and degradation rates measured at various monitoring points at each site. Table 2 provides a summary of initial and final soil and soil gas analytical results for total recoverable petroleum hydrocarbons (TRPH) and benzene, toluene, ethyl benzene, and xylenes (BTEX) at each site. Based on the results from your sites and 121 sites throughout the Air Force, bioventing is cost-effectively remediating fuel contamination in a reasonable time frame. We recommend that other sites at your facility be evaluated for possible use of this technology. The sites should be evaluated using the criteria in the AFCEE Test Plan and Technical Protocol for a Field Treatability Test for Bioventing, May 1992, including Addendum One, February 1994. These are found in the "Tool Box" recently sent to your base.

The objective of the one-year sampling and evaluation effort was not to collect enough samples for a statistical evaluation, but rather to demonstrate the feasibility of using bioventing to reduce TRPH and BTEX concentrations in fuel contaminated soil and soil gas. The results of soil and soil gas sample analyses and respiration testing were used to evaluate the performance of this technology for each site.

Soil gas samples are similar to composite soil samples in that they are collected over a larger vertical interval than a discrete sample collected at a specific depth. Thus, they provide an indication of changes in soil gas profiles and volatile contaminant concentrations (see Addendum One to Test Plan and Technical Protocol for a Field Treatability Test for Bioventing - Using Soil Gas Surveys to Determine Bioventing

AQ M01-02-0228

Feasibility and Natural Attenuation Potential, February 1994). Soil samples, on the other hand, are discrete point samples subject to large variabilities over small distances and/or soil types. Because of the wide variations inherent in the soil sample collection and analysis process, the analytical results from soil samples alone should not be viewed as conclusive indicators of bioventing progress or evidence of the success or failure of this technology. This point is well illustrated at the Elmendorf sites in that the TPH and BTEX concentrations in the soil gas samples decreased while the concentrations in many of the soil samples increased during the period of the study. For this reason, in situ respiration tests and associated soil gas sampling and analysis are considered better indicators of hydrocarbon remediation than limited soil sampling.

The following paragraphs provide site specific information on the analytical results from samples collected at the bioventing sites at Elmendorf AFB.

ST 43/55 Valve Pit 3-4 Area (Atch 1)

Comparison of initial and one year degradation rate data indicate that, at two of the locations, the one-year biodegradation rates are noticeably less than the original. The degradation rates at the third location, MPB-16.5, were higher than the initial rate. Review of the soil gas analyses indicate that the one-year TVH values for this location are still high, which would explain the consistent degradation rate. No comparisons could be made on the six-month respiration and degradation rates because no initial or one-year data were available for the points for which there was six-month data (Table 1).

A comparison of the initial and one-year soil gas analytical results for both points measured show a significant decrease with time in the concentrations of TVH and BTEX. These measurements indicate that fuel biodegradation is progressing at a significant pace. Initial concentrations of TPH and BTEX in the soils were very close to the detection limits, so the one-year soil results, understandably, did not reveal any significant change (Table 2).

ST 43/55 Pumphouse III (Atch 2)

Degradation rates at all three points measured showed a significant decrease between the initial and one-year sampling events, indicating a decrease in the amounts of fuel available for degradation. However, after one year, biodegradation rates were still significant (490 to 1800 mg/kg/yr) (Table 1).

Comparison of the initial and final soil gas analytical results indicated a decrease in TVH and BTEX concentrations at all locations sampled. These measurements indicate that

fuel biodegradation is progressing at a significant rate, both in the area adjacent to the vent well, and in the areas between the vent well and the monitoring points. Soil analytical results for this site are inconclusive. The TPH and BTEX concentrations in the soils at the vent well showed a significant decrease, but the soil concentrations at MPA-20 and MPB-17.5 showed a general increase (Table 2).

Site ST-61 (Atch 3)

Biodegradation rates at the vent well and one of the monitoring points decreased over the one year course of the study. Degradation rate increased at one of the monitoring points, MPA-4. Review of the initial and final soil gas analyses from this location reveal that the TVH levels are still relatively high at this location and, more significantly, that soil temperatures increased during this time period, possibly explaining the increase in degradation rate (Table 1).

TVH and BTEX concentrations in soil gas at the two points measured decreased significantly between the initial and the one-year sampling events, indicating that fuel biodegradation is progressing at a significant rate. The TPH concentrations in the soil increased at all three points measured, illustrating the point discussed previously that soil concentrations can be widely variable over small intervals and/or soil types. BTEX concentrations in the soils were insignificant both before and after bioventing; therefore, the soil BTEX data were inconclusive (Table 2).

Site ST-71 (Atch 4)

A comparison of initial and final degradation rates could only be made for two of the monitoring points. The degradation rates essentially remained unchanged at both points, indicating that there is fuel remaining in the subsurface in portions of the site. After one year, the degradation rates at this site indicate continuing biodegradation of hydrocarbons (Table 1).

TVH and BTEX concentrations in soil gas at the two points measured decreased significantly between the initial and the one-year sampling events, indicating that fuel biodegradation is progressing at a significant rate. Initial concentrations of TPH and BTEX in the soils were relatively low, so although the concentrations decreased at two of the locations and increased at one of the locations, the soil results were inconclusive (Table 2).

Based on the positive results of this evaluation, AFCEE recommends that the bioventing pilot system at each site continue to operate while planning for either closure sampling or continued monitoring. Funds are available for closure sampling at Site ST 61. However, based on the one-year results of the bioventing study and the Alaska soil clean-up regulations, AFCEE recommends that Site ST 71 be substituted for ST 61 for

closure sampling. The reason behind this recommendation is that the soil hydrocarbon levels at ST 71 are below Alaska clean-up levels and those at ST 61 are still above. Based on a comparison of the Alaska soil clean-up levels and the one-year soil hydrocarbons concentrations, continued monitoring is recommended at Sites ST-61 and ST 43/55 Valve Pit 3-4. Expansion to a full-scale system is recommended at Site ST-43/55 Pumphouse 3 due to the high hydrocarbon concentrations remaining in the soil. Continued monitoring and/or expansion to a full-scale bioventing system for any of these sites can be contracted through AFCEE. Please contact 2Lt Maryann Jenner, AFCEE/ERT, DSN 240-4364, COM 210-536-4364, to discuss technical and contractual options for full-scale expansion.

Data from your base and many others indicate that BTEX compounds are preferentially biodegraded over TRPH. Since BTEX compounds represent the most toxic and mobile fuel constituents, a BTEX standard is a risk-based standard. We strongly encourage its use over an arbitrary TPH standard. Within the AFCEE Risk-based Petroleum Hydrocarbon "Tool Box," the report entitled "Using Risk-based Standards will Shorten Cleanup Time at Petroleum Contaminated Sites" summarizes the BTEX/TPH issue and will assist you in negotiating for a BTEX cleanup standard.

In general, quantitative destruction of BTEX can be accomplished through bioventing. The time frame for this destruction to occur is based on a variety of factors such as initial contaminant concentrations, site lithology, and depth to groundwater. Soil gas surveys and respiration tests can be used as BTEX destruction indicators. If a non-risk-based/TRPH cleanup is chosen, the pilot and full-scale systems should be operated until respiration rates approach background rates. We recommend that confirmatory soil sampling be conducted four to six months after background respiration rates are approached.

Due to the streamlined nature of this evaluation project, the interim results report and this letter will be the only project documentation provided to the base. The interim results report contains site diagrams and analytical results from initial soil and soil gas samples. Attachments to this letter provide the analytical results for the final soil and soil gas samples and this letter provides a summary of the collected data and recommendations for follow-on activities. AFCEE is no longer responsible for the operation, maintenance, or monitoring of the bioventing sites. We have initiated a contract to extend monitoring at some sites beyond the initial one-year test. Monitoring will include soil gas and respiration tests to document hydrocarbon degradation, but also may include the collection of sufficient final soil samples to statistically demonstrate site cleanup. If you are interested, please call us.

The blowers and accessories are now base property and should continue to be used on this or other bioventing sites. Although the current equipment is explosion-proof, under no circumstances should it be used for soil vapor extraction unless

appropriate explosion-proof wiring is provided. If the base does not want to keep the blowers or if you have further questions, please contact us.

On behalf of the AFCEE/ERT staff, I would like to thank you for your support of these bioventing test and evaluation projects. The information gained from each site will be invaluable in evaluating this technology and will promote its successful application on other DOD, government, and private sites. I have attached a customer satisfaction survey. Please take a few minutes to fill it out and tell us how we did. We look forward to hearing from you.

ROSS N. MILLER, Lt Col, USAF, BSC
Chief, Technology Transfer Division

Attachments:
1. Valve Pit 3-4 Data
2. Pumphouse III Data
3. Site ST61 Data
4. Site ST71 Data
5. Survey

cc: HQ PACAF/CEVR
AFCEE/ERD (Mr. McGhee)
Engineering Science

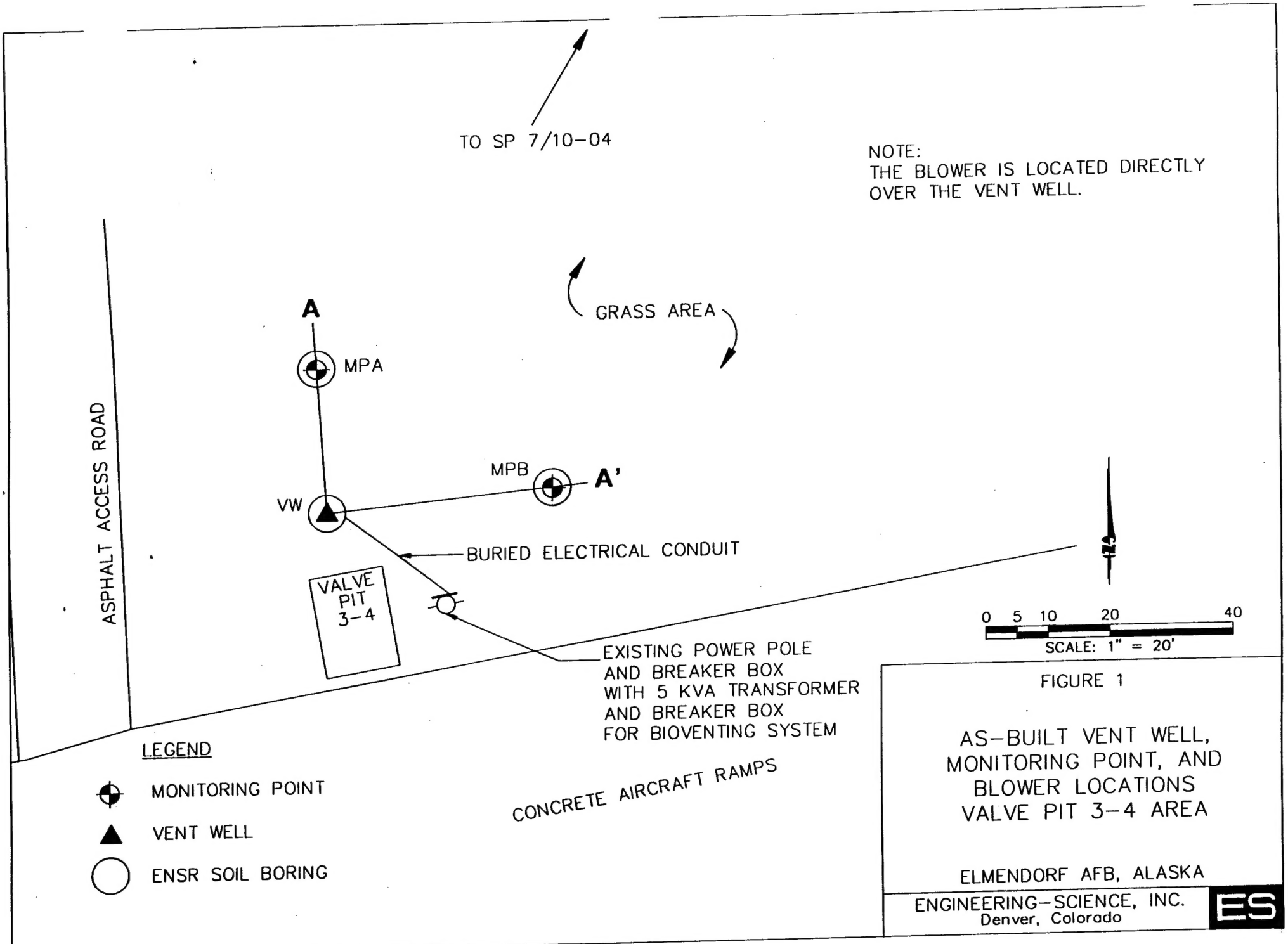

TO SP 7/10-04
NOTE:
THE BLOWER IS LOCATED DIRECTLY OVER THE VENT WELL.
GRASS AREA
A
MPA
MPB
A'
VW
ASPHALT ACCESS ROAD
BURIED ELECTRICAL CONDUIT
VALVE PIT 3-4
EXISTING POWER POLE AND BREAKER BOX WITH 5 KVA TRANSFORMER AND BREAKER BOX FOR BIOVENTING SYSTEM
CONCRETE AIRCRAFT RAMPS
0 5 10 20 40
SCALE: 1" = 20'
LEGEND
MONITORING POINT
VENT WELL
ENSR SOIL BORING
FIGURE 1
AS-BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS VALVE PIT 3-4 AREA
ELMENDORF AFB, ALASKA
ENGINEERING-SCIENCE, INC.
Denver, Colorado
ES

TABLE 1
ST43/55 VALVE PIT 3–4 AREA
RESPIRATION AND DEGRADATION RATES
ELMENDORF AFB, ALASKA

Location–Depth	Initial			6–Month[b/]			1–Year		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0051	1,430	NS[c/]	NS	NS	NS	0.0016	430	NS
MPA–12.5	NS	NS	3.6	0.00011	30	3.9	NS	NS	7.3
MPA–16.5	NS	NS	3.4	NS	NS	4.7	NS	NS	5.9
MPB–12.5	0.0063	1,800	NS	NS[d/]	NS	NS	0.0013	420	NS
MPB–16.5	0.0054	1,500	NS	NS[d/]	NS	NS	0.0050	1,600	NS

[a/] Milligrams hydrocarbons per kilogram soil per year.
[b/] Assumes moisture content of the soil is the average of initial and final moistures.
[c/] Not Sampled.
[d/] MPB had been buried under soil stockpile.

ABLE 2
SITE ST43/55 Valve Pit 3–4 Area
INITIAL AND 1–YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
ELMENDORF AFB, ALASKA

Analyte (Units)[a/]	Sample Locations–Depth (feet below ground surface)			
	VW		MPB–16	
Soil Gas Hydrocarbons	Initial[b/]	1–Year[c/]	Initial	1–Year[d/]
TVH (ppmv)	3100	0.43	24000	5400
Benzene (ppmv)	1.2	0.004	24	<3.4
Toluene (ppmv)	19	0.015	140	<3.4
Ethylbenzene (ppmv)	5.0	0.003	10	10.1
Xylenes (ppmv)	21	0.014	34	66.5

	VW–17.5		MPA–15		MPB–12.5	
Soil Hydrocarbons	Initial[e/]	1–Year[f/]	Initial	1–Year	Initial	1–Year
Diesel Range (mg/kg)	<6	<4.2	<6	16	<6	<4.2
Gasoline Range (mg/kg)	0.3	<0.11	0.9	<0.1	<0.07	<0.10
TRPH (mg/kg)	<5.3	<5.3	<5.3	9.4	9.1	<5.2
Benzene (mg/kg)	<0.0004	<0.0005	0.0073	<0.0005	<0.0004	<0.0005
Toluene (mg/kg)	<0.0004	<0.0005	0.0042	<0.0005	<0.0004	<0.0005
Ethylbenzene (mg/kg)	0.0036	<0.0005	0.012	<0.0005	<0.0004	<0.0005
Xylenes (mg/kg)	0.0063	<0.0007	0.037	<0.0007	<0.0008	<0.0007
Moisture (%)	5.3	6.3	5.9	4.1	5.7	3.5

[a/] TVH=total volatile hydrocarbons: ppmv = parts per million, volume per volume;
TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram.

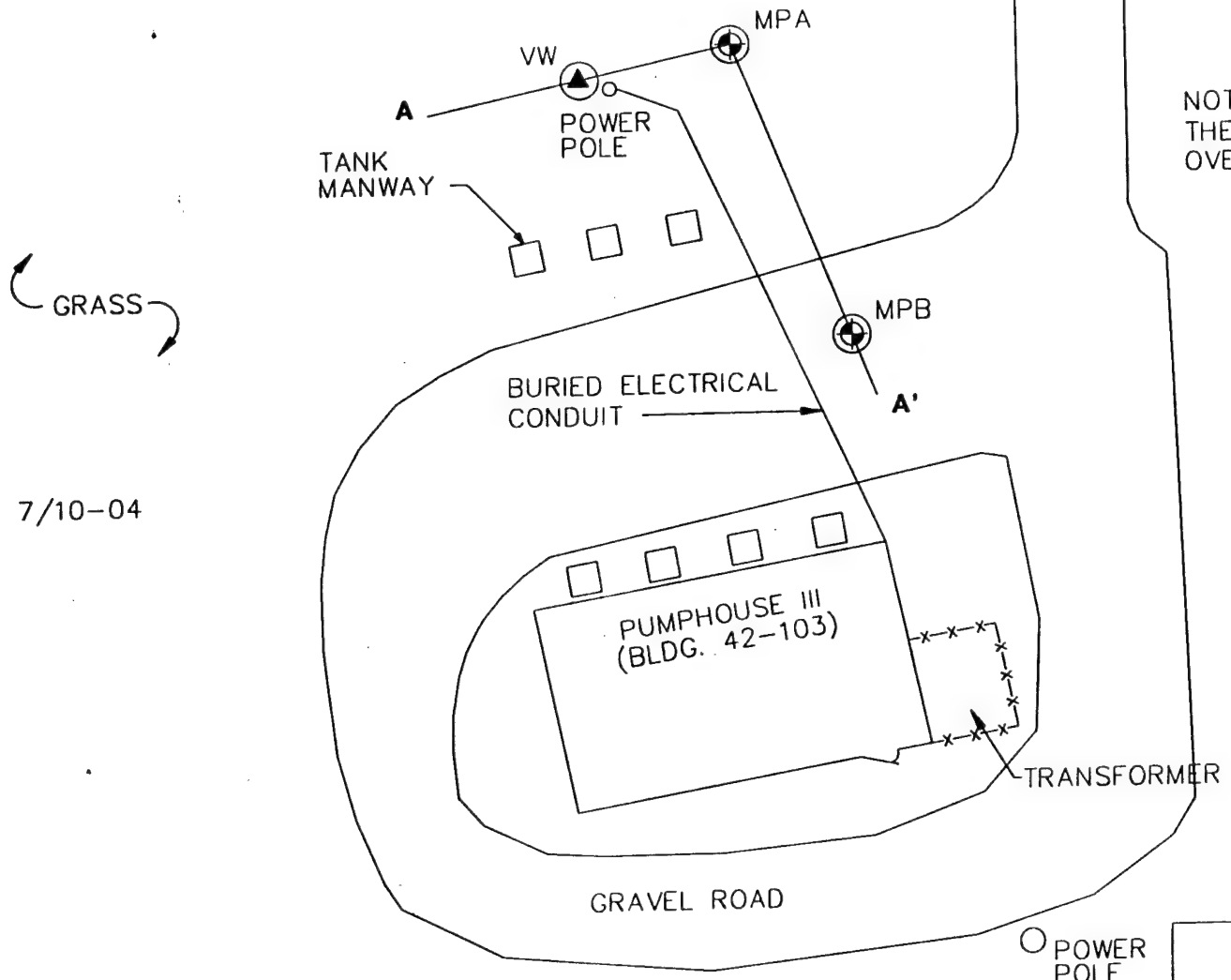
[b/] Intitial soil gas samples collected on June 24, 1993

[c/] Final soil gas samples collected on August 2–3, 1994

[d/] Average of duplicate samples.

[e/] Intitial soil samples collected on June 21–22, 1993

[f/] Final soil samples collected on August 9, 1994



NOTE:
THE BLOWER IS LOCATED DIRECTLY OVER THE VENT WELL.

LEGEND

- MONITORING POINT
- VENT WELL
- ENSR SOIL BORING
- EXISTING MONITORING WELL

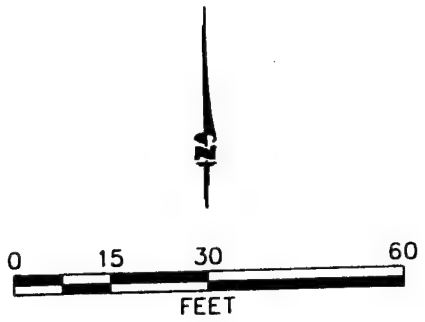


FIGURE 1

AS-BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS PUMPHOUSE III AREA

ELMENDORF AFB, ALASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

TABLE 1
ST43/55 PUMPHOUSE III
RESPIRATION AND DEGRADATION RATES
ELMENDORF AFB, ALASKA

Location–Depth	Initial			6–Month[b/]			1–Year		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0078	1,700	NS[c/]	NS	NS	NS	0.0017	490	NS
MPA–19	0.0066	1,100	NS	0.0013	180	NS	0.0045	500	NS
MPB–19	0.011	3,100	3.6	0.0017	400	6.5	0.0096	1,800	6.6

[a/] Milligrams hydrocarbons per kilogram soil per year
[b/] Assumes moisture content of the soil is the average of initial and 1–year moistures.
[c/] Not Sampled.

TABLE 2
SITE ST43/55 PUMPHOUSE III
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
ELMENDORF AFB, ALASKA

Analyte (Units)[a/]	Sample Locations–Depth (feet below ground surface)					
	VW		MPA–19		MPB–19	
Soil Gas Hydrocarbons	Initial[b/c/]	1–Year[c/]	Initial	1–Year	Initial	1–Year
TVH (ppmv)	14,000	5.8	28,000	1,900	17,000	420
Benzene (ppmv)	8.1	<0.002	30	<0.52	19	<0.085
Toluene (ppmv)	44.5	0.087	96	<0.52	51	<0.085
Ethylbenzene (ppmv)	14.5	0.03	16	3.8	15	1.8
Xylenes (ppmv)	53	0.12	52	15	46	2.3
	VW–20		MPA–20		MPB–17.5	
Soil Hydrocarbons	Initial[e/]	1–Year[f/]	Initial	1–Year	Initial	1–Year
Diesel Range (mg/kg)	1,460	85	2,140	6,110	220	1,820
Gasoline Range (mg/kg)	9,000	27	16,000	8,530	47[g/]	490
TRPH (mg/kg)	5,340	89.7	6,190	15,100	85	2,780
Benzene (mg/kg)	<5	<0.066	<5	<7.3	<0.04	<0.28
Toluene (mg/kg)	35	0.096	87	95	0.098	0.73
Ethylbenzene (mg/kg)	62	<0.066	94	94	0.16	1.2
Xylenes (mg/kg)	300	0.22	430	420	1.2	5.7
Moisture (%)	7.8[c/]	5.3	11	14.3	5.3	9.7

[a/] TVH=total volatile hydrocarbons: ppmv = parts per million, volume per volume;
TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram.

[b/] Intitial soil gas samples collected on July 12, 1993

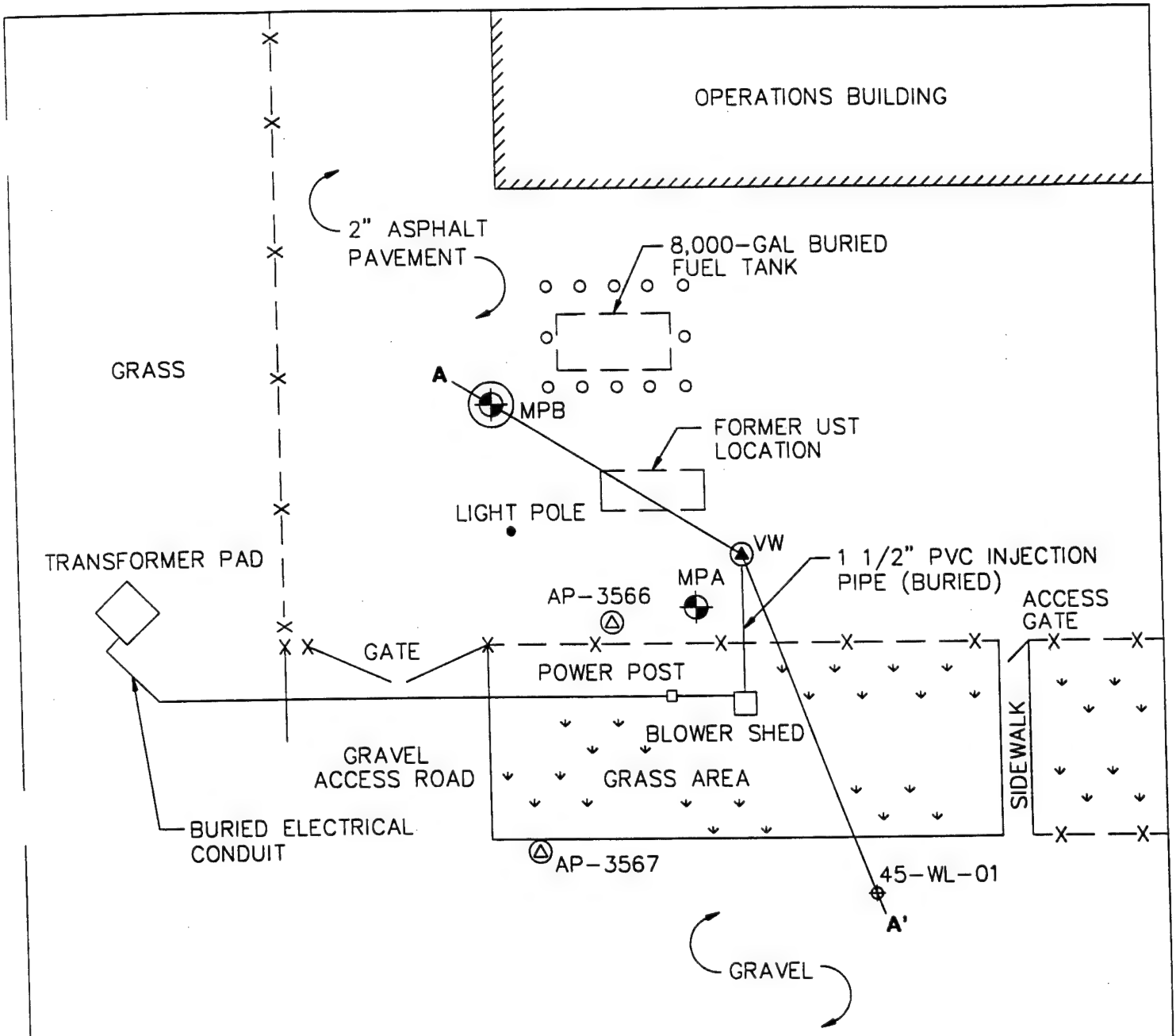
[c/] Average of duplicate samples.

[d/] Final soil gas samples collected on August 2, 1994

[e/] Intitial soil samples collected on July 2–6, 1993

[f/] Final soil samples collected on August 9, 1994

[g/] Hydrocarbons did not match profile of laboratory standard.



0 10 20 40

SCALE: 1" = 20'

LEGEND

- MONITORING POINT
- VENT WELL
- ENSR SOIL BORING
- ENSR MONITORING WELL
- EXISTING MONITORING WELL

FIGURE 1

AS-BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS SITE ST61

ELMENDORF AFB, ALASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

93DN0447, 10/05/93 at 10:00

TABLE 1
ST61
RESPIRATION AND DEGRADATION RATES
ELMENDORF AFB, ALASKA

Location–Depth	Initial			6–Month[b/]			1–Year		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0033	770	NS[c/]	NS	NS	NS	0.00063	130	NS
MPA–4	0.0015	320	13.6	0.0020	240	0.7	0.017	680	16.4
MPA–13	NS	NS	4.8	NS	NS	5.3	NS	NS	8.6
AP–3566	0.014	3200	NS	NS	NS	NS	0.0043	960	NS
AP–3567	NS	NS	NS	0.00040	90	NS	NS	NS	NS

[a/] Milligrams hydrocarbons per kilogram soil per year.
[b/] Assumes moisture content of the soil is the average of initial and final moistures.
[c/] Not Sampled.

ABLE 2
ST61
INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
ELMENDORF AFB, ALASKA

Analyte (Units)[a/]	Sample Locations–Depth (feet below ground surface)			
	VW		MPA-4	
Soil Gas Hydrocarbons	Initial[b/]	1-Year[c/]	Initial	1-Year
TVH (ppmv)	1200	3.4	890	400
Benzene (ppmv)	0.054	<0.002	0.052	<0.010
Toluene (ppmv)	0.41	0.005	0.22	0.44
Ethylbenzene (ppmv)	0.32	0.008	0.48	1.9
Xylenes (ppmv)	1.0	0.019	1.1	2.5

	VW-15		MPA-5		MPB-12.5	
Soil Hydrocarbons	Initial[d/]	1-Year[e/]	Initial[f/]	1-Year	Initial	1-Year
Diesel Range (mg/kg)	270	490	1530	5680	<6	<4.3
Gasoline Range (mg/kg)	34	94	62	160	<0.07	<0.11
TRPH (mg/kg)	260	748	1445	6420	<11	8.2
Benzene (mg/kg)	<0.05	<0.069	<0.05	<0.15	<0.0004	<0.0005
Toluene (mg/kg)	<0.05	<0.069	<0.05	0.26	0.001	<0.0005
Ethylbenzene (mg/kg)	0.22	<0.069	0.47	0.64	<0.0004	<0.0005
Xylenes (mg/kg)	0.12	0.44	0.60	1.8	0.0019	<0.0007
Moisture (%)	7.8	9.0	8.8	18.2	8.3	7.6

[a/] TVH=total volatile hydrocarbons: ppmv=parts per million, volume per volume;
TRPH = total recoverable petroleum hydrocarbons:mg/kg = milligrams per kilogram.

[b/] Initial soil-gas samples collected on July 2, 1993.

[c/] Final soil gas samples collected on August 1, 1994.

[d/] Initial soil samples collected on June 30–July 1, 1993.

[e/] Final soil samples collected on August 10, 1994.

[f/] Average of duplicate samples.

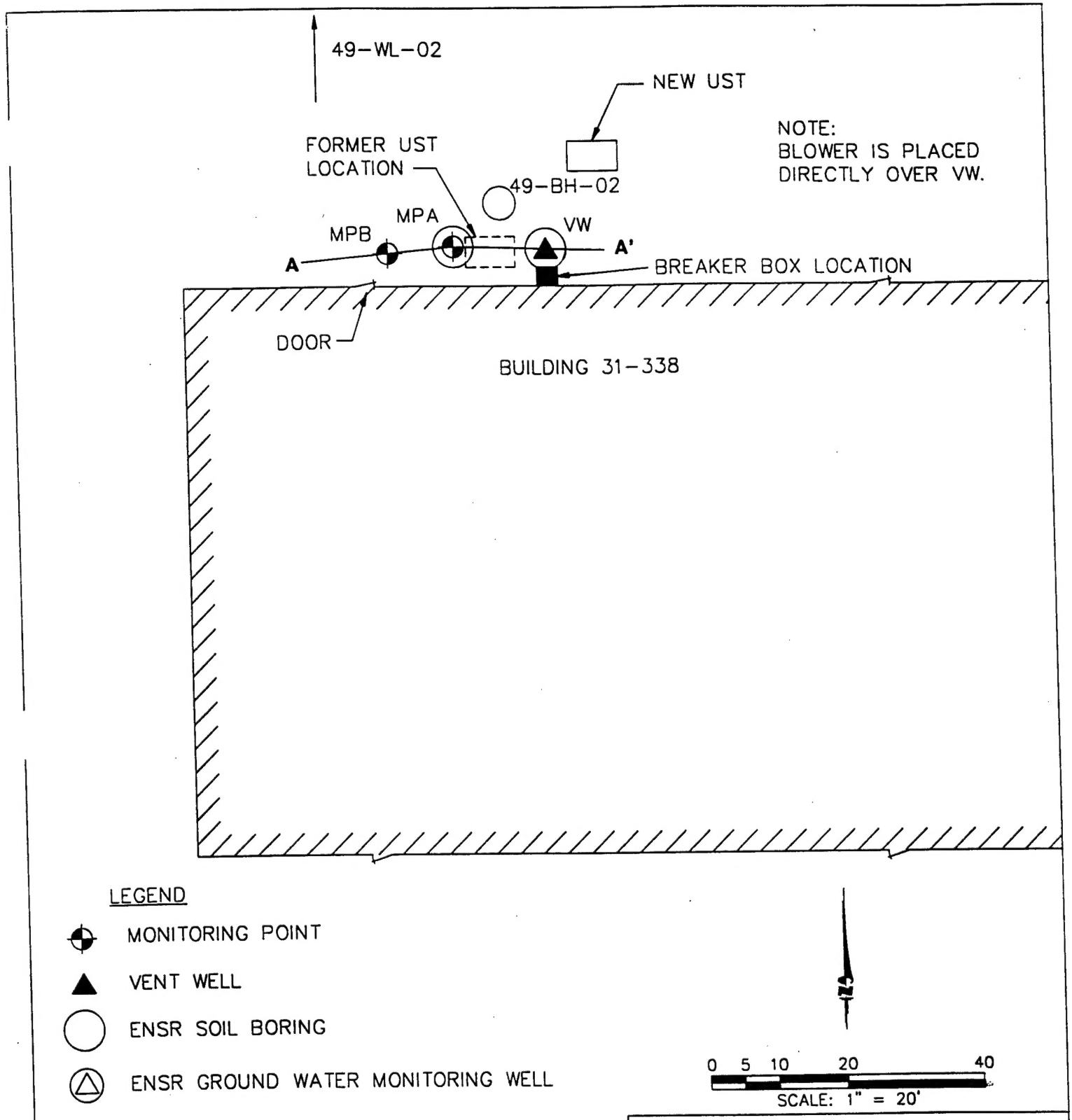


FIGURE 1

AS-BUILT VENT WELL,
MONITORING POINT, AND
BLOWER LOCATIONS
SITE ST71

ELMENDORF AFB, ALASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

93DN0445, 10/05/93 at 10:30

TABLE 1
ST71
RESPIRATION AND DEGRADATION RATES
ELMENDORF AFB, ALASKA

Location–Depth	Initial			6–Month[b/]			1–Year		
	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.00035	120	NS[c/]	NS	NS	NS	NS	NS	NS
MPA–4	0.000086	30	10.1	NS	NS	2.2	NS	NS	13.2
MPA–10	NS	NS	6.3	NS	NS	4.4	NS	NS	10.1
MPB–4	0.00032	100	NS	NS	NS	NS	0.00049	140	NS
MPB–10	0.0030	840	NS	0.00025	70	NS	0.0015	420	NS

[a/] Milligrams hydrocarbons per kilogram soil per year.
[b/] Assumes moisture content of the soil is the average of initial and final moistures.
[c/] Not Sampled.

TABLE 2
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INITIAL AND 1-YEAR SOIL AND SOIL GAS ANALYTICAL RESULTS
ELMENDORF AFB, ALASKA

Analyte (Units) [a]	Sample Locations-Depth (feet below ground surface)			
	MPA-4		MPB-10	
Soil Gas Hydrocarbons	Initial [b]	1-Year [c]	Initial	1-Year
TVH (ppmv)	480	1.0	290	5.4
Benzene (ppmv)	<0.049	<0.002	<0.012	<0.002
Toluene (ppmv)	<0.049	0.003	<0.012	0.005
Ethylbenzene (ppmv)	0.32	<0.002	0.12	0.063
Xylenes (ppmv)	2.1	0.008	0.13	0.058

	VW-10		MPA-10		MPB-4	
Soil Hydrocarbons	Initial [d]	1-Year [e]	Initial	1-Year	Initial	1-Year
Diesel Range (mg/kg)	<6	<4.2	140	<4.2	120	<4.2
Gasoline Range (mg/kg)	<0.073	1.8	0.12	<0.11	<0.07	0.36
TRPH (mg/kg)	12	<5.2	52	74	33	<5.3
Benzene (mg/kg)	<0.0004	<0.0005	<0.0004	<0.0005	<0.0004	<0.0005
Toluene (mg/kg)	<0.0004	0.0014	<0.0004	<0.0005	<0.0004	0.0012
Ethylbenzene (mg/kg)	<0.0004	<0.0005	<0.0004	<0.0005	<0.0004	<0.0005
Xylenes (mg/kg)	<0.0008	0.0009	<0.0008	<0.0007	<0.0008	<0.0007
Moisture (%)	4.5	4.2	5.8	5.8	3.4	5.4

[a] TVH=total volatile hydrocarbons: ppmv=parts per million, volume per volume;
TRPH = total recoberable petroleum hydrocarbons:mg/kg = milligrams per kilogram.

[b] Initial soil gas samples collected on June 18, 1993.

[c] Final soil gas samples collected on August 1, 1994.

[d] Initial soil samples collected on June 16, 1993.

[e] Final soil samples collected on August 8, 1994.